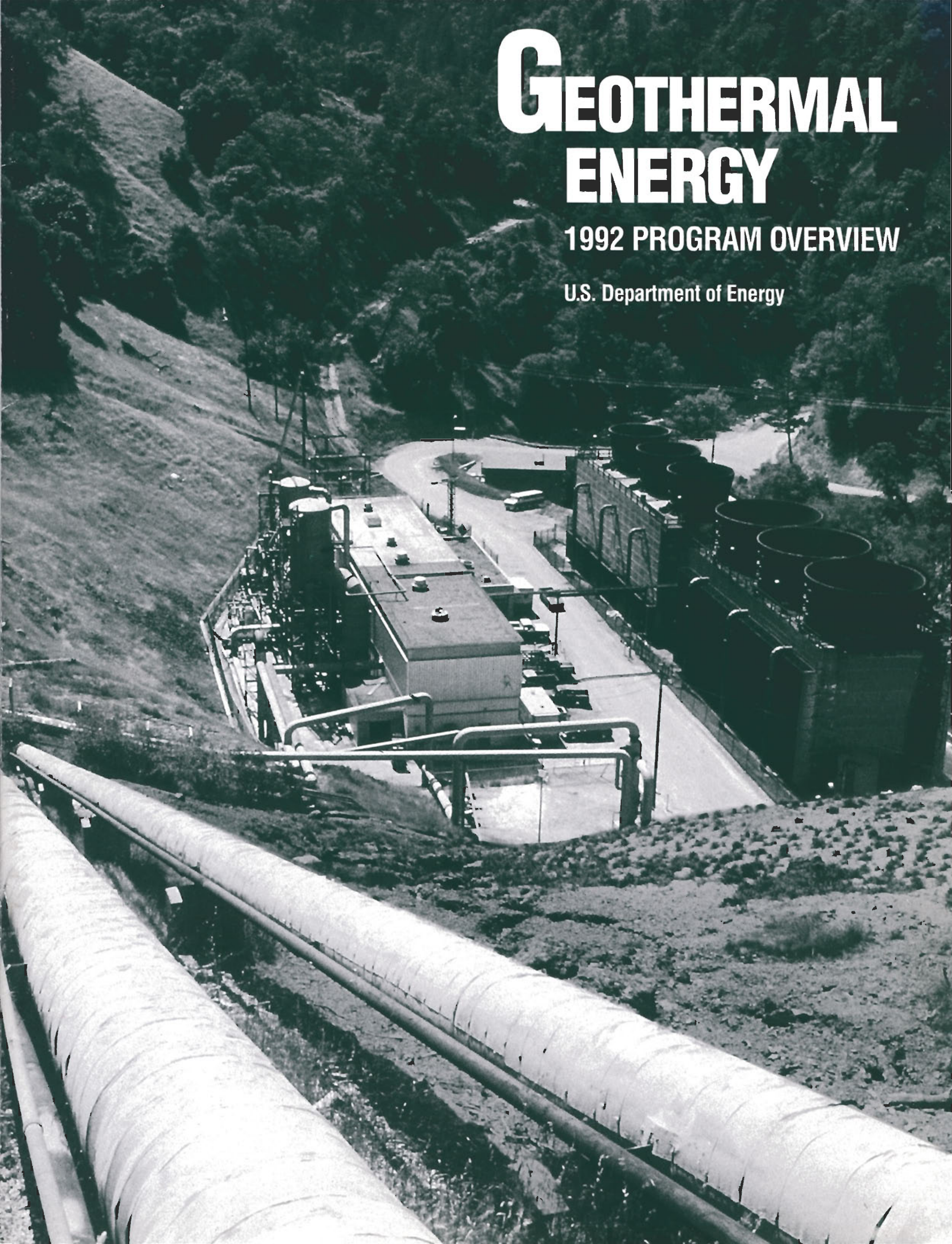
GEOTHERMAL ENERGY

1992 PROGRAM OVERVIEW

U.S. Department of Energy



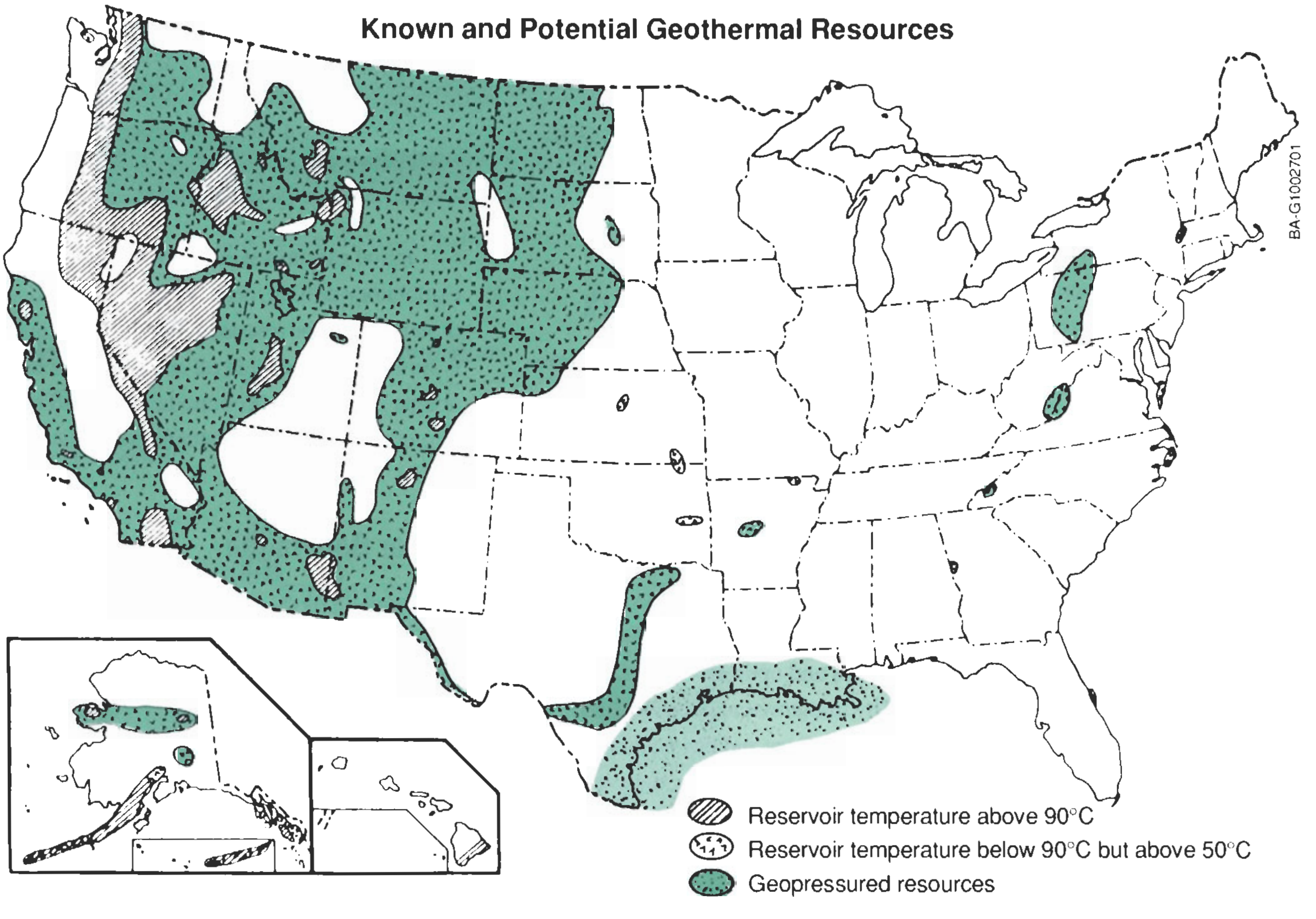
Cover photograph of The Geysers courtesy of Pacific Gas and Electric Company

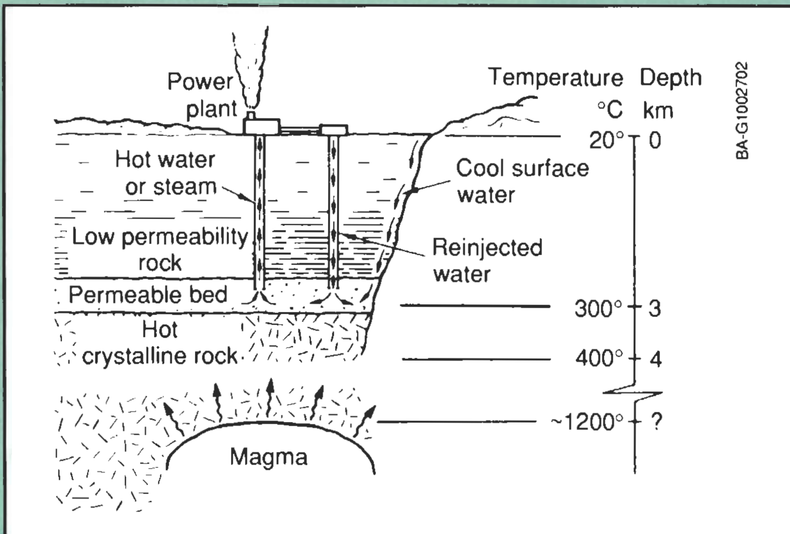
INTRODUCTION

Geothermal energy is a domestic energy source that can produce clean, reliable, cost-effective heat and electricity for our nation's energy needs.

Geothermal energy—the heat of the earth—is one of our nation's largest energy resources. In fact, geothermal energy represents nearly 40% of the total U.S. energy resource base and already makes an important contribution to our nation's energy needs. Geothermal energy systems can provide clean, reliable, cost-effective energy for our nation's industries, utilities, businesses, and homes in the form of heat and electricity. The U.S. Department of Energy's (DOE) Geothermal Energy Program sponsors research aimed at developing the science and technology necessary for tapping this resource more fully.

Geothermal energy originates from the earth's interior. The hottest fluids and rocks at accessible depths are associated with recent volcanic activity, particularly in the western states, Alaska, and Hawaii. In some places, heat comes to the surface as natural hot water or steam, which have been used since prehistoric times for cooking and bathing. Today, wells convey the heat from deep in the earth to electric generators, factories, farms, and homes.





A typical hydrothermal system.

The Four Types of Geothermal Energy

Geothermal energy occurs in four different forms. **Hydrothermal fluids**—hot water or steam—are the easiest to access and therefore are the only forms currently being used commercially. Hydrothermal resources are found from a hundred meters to several kilometers below the earth's surface. The temperature of these fluids can be as high as 380°C.

Geothermal energy is also found in the form of **geopressured brines**. These brines are hot pressurized waters that contain dissolved methane and lie at depths of about 3 km to more than 6 km. The best characterized geopressured reservoirs lie along the Texas and Louisiana Gulf Coast.

Hot dry rock energy consists of relatively water-free, impermeable rock at high temperatures. To use that energy, an artificial reservoir is created by pumping high-pressure water into the rock to open existing fissures. Heat is extracted from the rock by drilling two (or more) wells into the reservoir and injecting cool water down one of them. The water absorbs heat as it circulates through the fractures before being recovered through the second well. At the surface, heat is extracted from the water, which is then injected back into the first well in a closed-loop recirculating system.

Magma is molten or partially molten rock that reaches temperatures of nearly 1200°C. Some magma bodies are believed to exist at drillable depths within the earth's crust, although practical means of extracting magma energy have yet to be developed.

Putting the Resource to Work

The first steps in using a geothermal resource are locating a reservoir, determining its size and quality, and designing a strategy for developing and managing the field. The geosciences and drilling are used in each of these steps and in every stage of field development.

The geosciences—geology, geophysics, geochemistry, and hydrology—help to characterize subsurface properties and optimize well placement. For example, in hydrothermal applications, geologic models define the geometry and physical properties of the reservoir, geochemical models analyze changes in reservoir fluids and rocks, and numerical simulations predict long-term reservoir behavior. Other types of geothermal resources have their own special geoscience requirements.

Initial subsurface assessments are followed by exploratory drilling, production testing, and actual production of the resource. The drilling equipment is similar to that used in oil and gas fields but with unique features to accommodate the need to drill through hard, hot rock containing chemically hostile fluids.

Power Generation

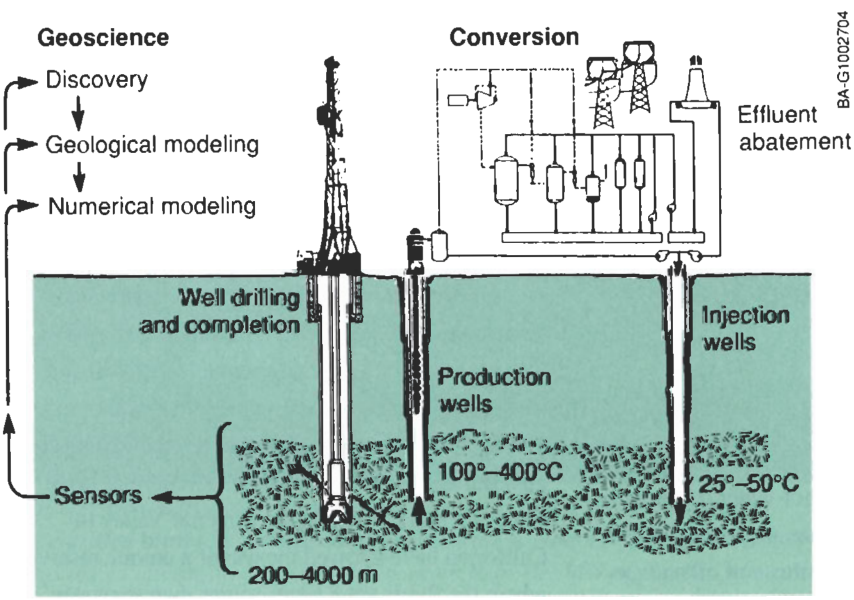
Today, a total of about 2800 megawatts of electric power (MW_e) generating capacity has been installed at a number of hydrothermal resource sites in the western states and Hawaii. Depending on the state of the resource (liquid or vapor), its temperature, and its chemistry, one of three different energy conversion technologies can be used to convert the thermal energy to electric power:

- **Dry Steam**—Conventional turbine-generators are used with dry steam resources. The steam is used directly, eliminating the need for boilers and boiler fuel that characterizes other steam power generating technologies.

- **High-Temperature Liquid**—For hydrothermal liquids above 200°C, flash steam technology is usually employed. In these systems, the liquid is allowed to flash one or more times to steam, which is used to drive a turbine.

- **Moderate-Temperature Liquid**—For liquids with temperatures less than 200°C, binary cycle technology is most cost-effective. In these systems, the hot geothermal liquid vaporizes a secondary working fluid, which then drives a turbine.

Geothermal energy has the potential to supply a significant fraction of the nation's energy use. In 1990, renewable energy generated more than 290 billion kilowatt-hours (kWh) of electricity, or roughly 10% of the nation's electricity. Geothermal power generated 20 billion kWh of electricity in 1990, which was about 7% of the electricity generated from renewable sources. DOE's National Energy Strategy predicted that by 2030, geothermal electric power production could increase more than tenfold, providing 184 billion kWh. Based on the same projections, by 2030 geothermal power will produce 25% of the electricity to be generated by renewable energy and 3% of the total electrical generation. And new legislation should enhance the contribution of geothermal energy—the passage of the Energy Policy Act of 1992 is expected to both reduce the nation's total electric generation and boost the production of electricity from renewable energy.



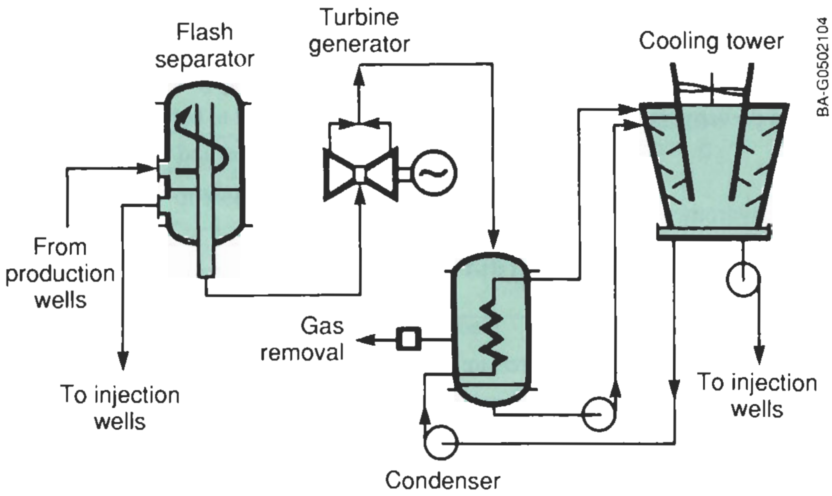
Geothermal power production components.

Direct Use

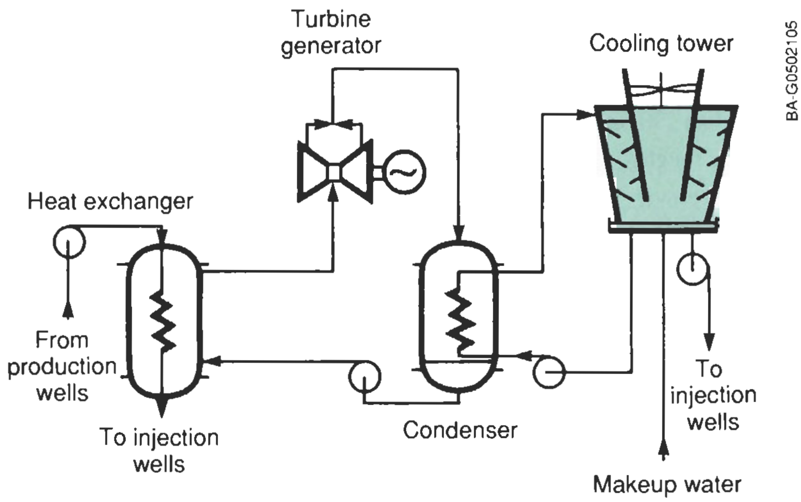
Geothermal resources at virtually all temperatures are suitable for direct-heating applications. The technology for direct use is drawn mainly from conventional hot-water and steam-handling equipment. For example, several communities use geothermal energy in district heating systems that provide heat to groups of homes or public buildings. In these systems, the geothermal production field (consisting of wells, pumps, and collection lines) replaces the boiler. Geothermal energy also provides direct heat for commercial greenhouses, fish hatcheries, food-processing plants, thermal-enhanced oil recovery, and a variety of other applications.

Another direct-use application is the ground-source or geothermal heat pump (GHP). GHPs use the same principles as the familiar air source heat pump, but take advantage of the earth's relatively constant ground temperature as a heat source in winter and a heat sink in summer. GHPs save 30% more energy than conventional heat pumps, which are dependent on widely fluctuating outside air temperatures. Geothermal heat pumps are applicable throughout the United States and have proven to be an ideal demand-side management technology for utilities.

In supporting documentation for the National Energy Strategy, the Energy Information Administration ranked the potential of GHPs second only to wood/biomass in dispersed applications. In 1991, U.S. energy use totaled approximately 86×10^{18} joules, or 86 exajoules (EJ). GHPs have the potential to supply 2.8 EJ by 2030, up from less than 0.1 EJ in 1991. To help encourage the growth of GHPs to meet this potential, the geothermal program in fiscal year (FY) 1992 conducted research to develop more rapid, economical emplacement of GHP heat-exchange coils, and sponsored the *Geothermal Heating and Cooling Teleconference* '92. This was the first of several teleconferences



Flash-steam technology for high-temperature liquids.



Binary cycle technology for moderate-temperature liquids.

designed for state energy officials, utility executives, building contractors, architects, and engineers to inform them about the benefits of GHPs. The first conference was viewed by a national audience of more than 3500 state energy officials and utility executives.

Geothermal Technology Today

When the federal Geothermal Energy Program was established in 1971, the United States had less than 200 MW_e of generating capacity in operation—all at The Geysers dry steam field in northern California—and industry's first hot-water demonstration plant was 9 years in the future. Geothermal drilling costs were up to 4 or 5 times those of oil and gas drilling, yet drilling was necessary to identify and characterize reservoirs in the absence of reliable geoscientific techniques. The chemically aggressive brines of some major reservoirs would corrode and erode turbine blades, plug injection wells, and deposit scale in wells, piping, and valves, impairing their operation.

In retrospect, considerable strides have been made in the technologies used to develop hydrothermal resources and the other geothermal energy forms. Drilling, operating, and maintenance costs for hydrothermal fields have decreased, and reliability has greatly improved. Better understanding of the character and performance of geopressured and hot dry rock reservoirs has brought these energy sources closer to commercial reality, and scientific evidence is available to show that the intense heat of magma may one day be commercially extracted. All technologies that have the potential to be economically feasible in the near term will continue to be advanced through program-sponsored research and cooperation with industry.

Hydrothermal Technology

The technology for using the hydrothermal resource has a long history of research and commercial development. Many direct-use applications have matured to the point where small projects for space heating, greenhouses, and industrial process heat are common throughout the West. The Geothermal Energy Program supports the transfer of these technologies to the private and public sectors through the Geo-Heat Center at the Oregon Institute of Technology.

Electricity production from hydrothermal resources has also seen significant development. The Geysers has become the world's largest geothermal complex, today producing nearly 1500 MW_e from 22 operating units; another 47 plants, operating in three states, are generating an additional 870 MW_e from hot water. DOE-sponsored research has contributed significantly to this development. For example, the results of cooperative research between government and industry at the Geothermal Loop Experimental Facility in the Imperial Valley of California have allowed the use of a unique reservoir where the fluids are 8 times saltier than seawater. A 45-MW_e plant now stands on the site of the experimental facility in an area estimated to have a 2000-MW_e capacity. Five other nearby plants also depend on the crystallizer/clarifier technology developed at the experimental facility.

Despite the progress made since the early 1970s, however, several obstacles remain to the widespread use of the hot water hydrothermal resource. Areas that need more research include drilling technology, binary cycle energy conversion technology, materials compatibility and lifetime, and techniques for locating and characterizing resources and for disposing of spent geothermal fluids. These areas are the focus of continuing DOE research.


Geothermal Resources Council

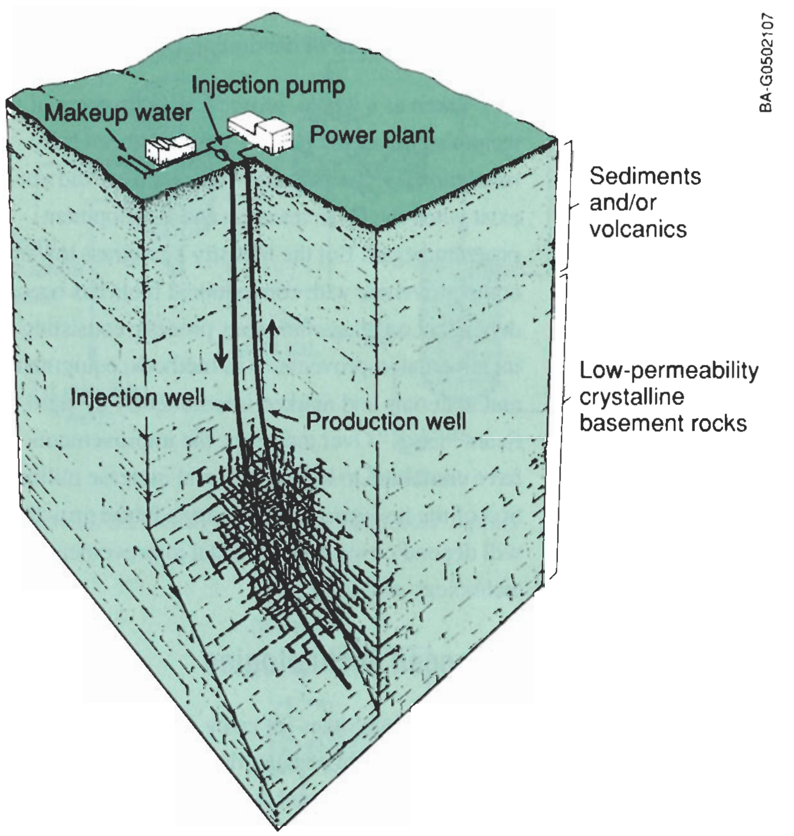
DOE research helped develop the technology to produce power from the concentrated brines in California's Imperial Valley. Now 15 commercial power plants are in operation there, providing more than 400 MW of electric generating capacity in southern California.

Taken as a whole, progress in hydrothermal technology over the past 15 years has been truly *revolutionary*; the U.S. hot water industry did not exist when the DOE research and development program began. But the industry's progress toward competitiveness with conventional fuels has been dependent on an *evolutionary* process, consisting of incremental improvements in methods, equipment, and materials and marked intermittently by significant "firsts." Over the years, the improvements have combined to lower costs and increase utilization of the resource. The industry's future growth will depend on such incremental improvements in technology and costs.

Advanced Technologies

The technologies for using the energy found in geopressured brines, hot dry rock, and magma, although less developed than those for hydrothermal energy, have advanced significantly in the past two decades. Data obtained from geopressured test wells in Louisiana and Texas indicate the energy source is large and usually saturated with methane and can be developed with minimal operational or environmental problems. Research has eliminated the problems of scaling, bringing the technology nearer to commercial application. The operation of a 1-MW_e demonstration hybrid power system for 8 months at the Pleasant Bayou site in Texas proved the technical feasibility of power generation from geopressured brines, but the process is not economical at today's low natural gas prices. In FY 1992, DOE research on geopressured energy was discontinued to focus on priority needs for hydrothermal energy.

Hot dry rock technology was proven on a small scale in the late 1970s by experiments at a site called Fenton Hill in New Mexico. A geothermal reservoir was created by hydraulically fracturing the rock mass between two wells at a depth of about 2750 m and circulating water down one well and up the other. The test produced enough heat—up to 5 megawatts of thermal energy (MW_t)—to satisfy the electricity needs of several hundred people. A



The hot dry rock process circulates water down an injection well and through man-made fissures in the rock, returning hot water for power production through the production well.

much larger, deeper, and hotter reservoir has since been completed, and an ongoing long-term test will increase our knowledge of the characteristics of hot dry rock reservoirs. To make this technology competitive, cost-effective methods must be developed to create and map fractures in underground rocks and to drill wells in abrasive, hot rocks.

The scientific feasibility of extracting energy from magma was proven by DOE experiments at a shallow, encrusted lava lake in Hawaii. However, the technology to locate subsurface magma chambers and extract energy from them economically has yet to be developed. The economic feasibility of magma energy will depend on the accessibility, the costs and lifetimes of wells, and the effectiveness of various energy extraction techniques. In FY 1991, DOE research on magma energy was discontinued to focus on priority needs for hydrothermal energy.

Research in geopressured brines, hot dry rock, and magma has been justified by the tremendous potential these energy sources offer:

- An economic analysis of hot dry rock technology, performed by the Massachusetts Institute of Technology during FY 1990, indicates that with lower drilling and completion costs, U.S. hot dry rock energy sources with temperature gradients greater than 30°C per kilometer could provide over 2,300,000 MW_e for 200 years at a weighted average cost of $0.057/kWh. The current U.S. electric generating capacity totals about 700,000 MW_e.
- The potential power production from domestic geopressured energy sources has been estimated by the U.S. Geological Survey to be 23,000 to 240,000 MW_e for 30 years. The methane content of the brines is estimated at 161 trillion m^3 (5700 trillion ft^3), by far the largest natural gas resource.
- Crustal magma bodies in the United States are believed to contain up to 530,000 EJ of thermal energy at temperatures in excess of 600°C and at depths less than 10 km. This is more than 6000 times greater than the total U.S. energy use in 1991.

Energy production from even a small fraction of these resources would greatly enhance the nation's domestic energy supplies.

Program Approach

The Geothermal Energy Program supports research and development of technology that will allow geothermal energy to contribute more fully to our nation's energy supply. Specific projects are carefully selected based on their expected impact, chance of technical success, and pertinence to industry needs. The program interacts regularly with the geothermal industry to focus program priorities, and involves industry members in cooperative research and technology transfer. Progress within the program is measured against cost objectives for electricity generated from hydrothermal energy along with technology improvement objectives for the other forms of geothermal energy.

RESEARCH ACCOMPLISHMENTS FOR FY 1992

In FY 1992, the Geothermal Energy Program made significant strides in hydrothermal, geopressured brine, and hot dry rock research, continuing a tradition of advances in geothermal technology.

Hydrothermal Research

A major portion of program research is dedicated to developing technologies applicable to hydrothermal resources. Research within this category is organized into three tasks:

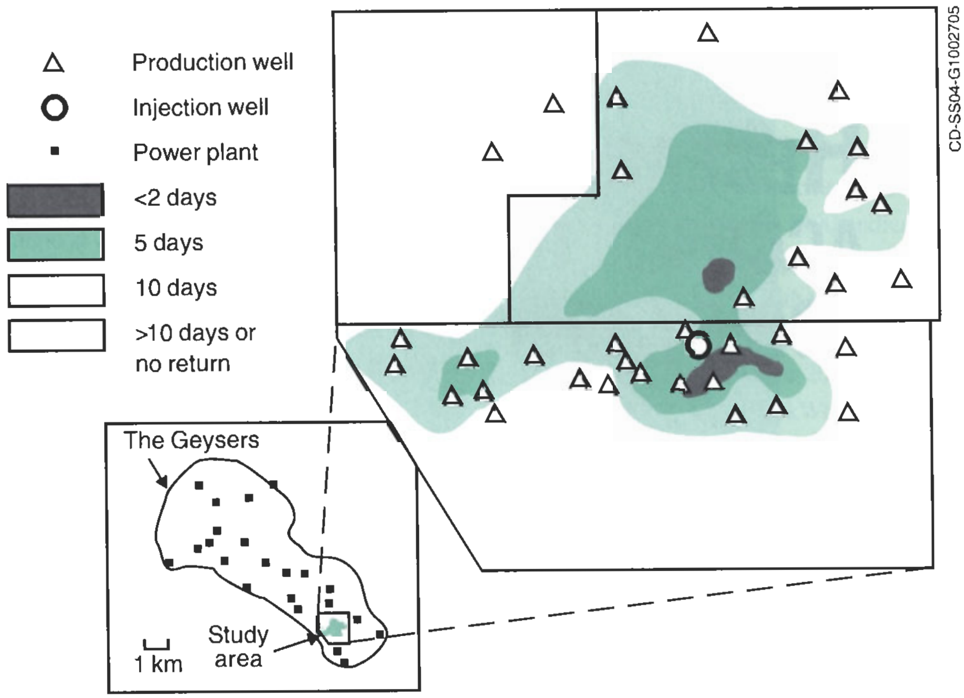
- Reservoir technology
- Drilling technology
- Energy conversion technology.

Reservoir Technology

Reservoir technology research supports the U.S. geothermal industry by advancing the methods and technologies for exploration, development, and long-term operation of commercial geothermal fields. In FY 1989, the Reservoir Technology Research Task initiated a broad, continuing program of studies related to understanding and solving critical problems at The Geysers steam field in California. In cooperation with the geothermal industry, this DOE-funded research program has focused on optimizing water injection to recharge the reservoir and on understanding reservoir conditions, which control the flow of steam to production wells.

Pacific Gas and Electric Company

DOE research at The Geysers is assisting operators with their efforts to optimize the reinjection of water, which maintains reservoir pressure and helps replenish production wells.



Tracer injection tests help producers understand the fluid flow within geothermal reservoirs. The contours in this diagram represent the time required for the tracer chemical to spread outward from the injection well.

Exploration Technology. Exploration technology research provides new methodologies for industry to discover and evaluate new geothermal fields. A DOE-funded exploration well in Long Valley, California, is providing significant information about the structure and history of the hydrothermal system there. The well reached 2300 m in FY 1992, and researchers have performed a number of experiments in the well to evaluate the effectiveness of new analytical tools and methods.

Joint DOE/industry case studies for exploration were also initiated in FY 1992 at several producing geothermal fields. These case studies are using geochemical techniques and seismic, electrical, and thermal geophysics to evaluate the fields; that information is being checked against the actual development of the field to help calibrate the exploratory techniques. The intent is to produce an accurate, integrated process to evaluate geothermal fields using all available technologies. This process will eventually include new techniques now being investigated, such as remote sensing and biogeochemistry.

Reservoir Analysis. Reservoir analysis research emphasizes the development of new analytical and interpretive methods for predicting reservoir performance. In FY 1992, microseismic techniques were used to measure the attenuation and velocity of seismic waves through a geothermal reservoir, helping to determine the location of fractures and the character of the fluid in those fractures. A further understanding of reservoir dynamics was gained by determining the amount of water adsorbed on fracture surfaces and estimating the potential energy recovery from that adsorbed water. These accomplishments will allow industry to calculate more accurately the productive lifetime of a reservoir and to assess the volume of reservoir needed to provide the production of a well.

Joint research with the geothermal industry in FY 1992 has resulted in the testing and verification of a new reservoir simulator. This computer code is now being applied to various parts of The Geysers steam field by the operating companies there, and the results are being used to develop new injection strategies.

Brine Injection. Commercial geothermal operations require the majority of produced fluids to be injected to maintain reservoir pressures and to support production. Research is needed to optimize injection and to avoid cold water breakthrough to nearby production wells. In FY 1992, a joint DOE/industry experiment continued to test and evaluate easily detectable organic tracers, proving them to be very useful in determining flow paths. The tracer tests are now being used independently by the geothermal operators, and many operators have used the results of these tests to improve their injection and production strategies.

Geothermal Technology Organization. The Geothermal Technology Organization (GTO) is a cooperative DOE/industry group formed to encourage technology development related to reservoir performance and energy conversion. The organization supports projects that lead to products or services that can be commercialized immediately. Projects are jointly funded by DOE and participating industry partners, with industry providing at least 50% of the total cost. The organization and its sister group, the Geothermal Drilling Organization (GDO), frequently provide the test sites for investigating new technology and methods. In FY 1992, GTO funded joint projects for the protection of wells from corrosive gases and for the development of new seismic analysis techniques.

Drilling Technology

Drilling technology research pursues the development of drilling and well completion technologies that will considerably reduce the cost of geothermal wells. Geothermal drilling costs are high because of the hard rock, high temperatures, highly corrosive fluids, and problems with lost circulation—the loss of fluids circulated to cool and lubricate drill bits. Because the cost of well field development represents approximately one-third the cost of a geothermal project, reductions in drilling costs are important for the expansion of the industry.

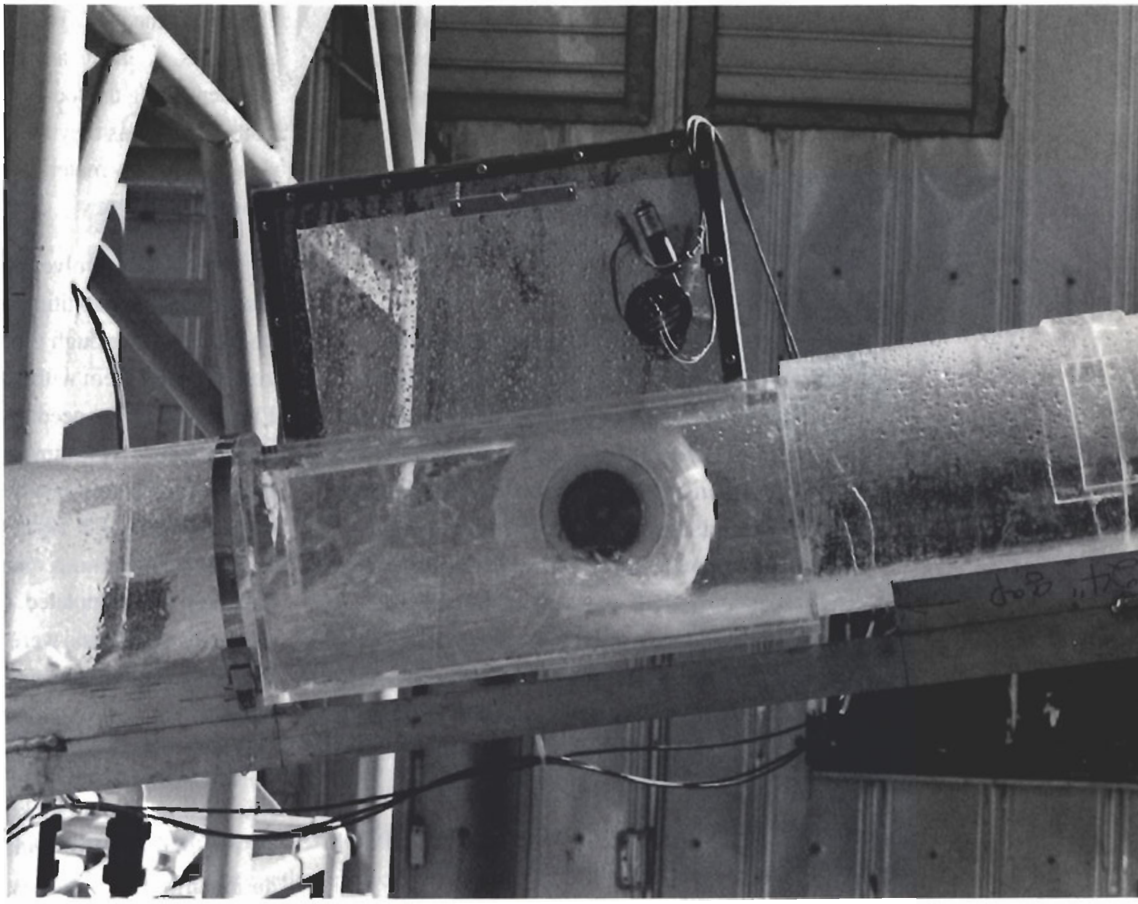
Lost Circulation Control. The most costly aspect of geothermal drilling is the loss of circulation in the drilling fluid system. Loss of circulation occurs when the drilling fluids flow into fractures or voids in the rock, rather than returning up through the borehole. Lost circulation episodes result in downtime and expensive corrective measures and can constitute 20% to 30% of the cost of a well. They also can result in more severe problems, such as borehole instability or stuck drill strings, that could lead to the loss of the well. To reduce the costs of these problems, scientists are developing new techniques for identifying the location and magnitude of loss zones as soon as they are encountered, and are developing new materials and techniques for plugging those zones.

One effort involves developing new, high-temperature, cementitious muds or cements that can be introduced through the drill pipe into the loss zones to plug them without removing the drill string. Elimination of the need to remove the drill string will greatly reduce downtime and aid in the location of the fractured zones, resulting in considerable cost savings. During FY 1992, the first phase of an effort to model cementitious mud flow into a lost circulation zone was completed. Mathematical models and computer algorithms were developed to simulate the flow of a cementitious mud or cement into a heated fracture.

To help monitor circulation fluid loss, a prototype flow meter for quickly detecting and measuring the rate of outflow of drilling fluid from a well during drilling was successfully field tested. Several drilling service companies have expressed interest in this rolling-float flow meter. Researchers also developed new components for the drillable straddle packer, an experimental tool for plugging lost circulation zones; completed a detailed design for the drillable straddle packer; used a new well-bore hydraulics flow facility to test a prototype downhole flow tool; and field tested a technique for measuring downhole fracture apertures with an acoustic borehole televiewer.

Rock Penetration Mechanics. Research in rock penetration mechanics is directed at improving drilling and coring systems to reduce costs. Efforts include the development of revolutionary advances in data transmission methods for measurement-while-drilling (MWD) systems and incremental advancements in drilling and coring systems.

Previous studies indicated that telemetry by acoustical carrier waves within the drill string can improve data collection rates 100-fold over the mud-pulse telemetry that industry uses today for MWD. In FY 1992, two patents were awarded to Sandia National Laboratories for this technology. Researchers



DOE research has led to new advances in drilling technology, such as this flow meter for measuring the outflow of drilling fluid from a well. Such developments could lower the cost of drilling geothermal wells and encourage greater use of geothermal resources. The petroleum industry has expressed interest in this new flow meter.

also developed and published a theoretical model for the attenuation of the acoustical carrier waves in the drill string.

Instrumentation. Better downhole instrumentation for gathering data is needed to improve the reliability of data used in exploration and reservoir analysis. The recent focus of this effort is on slimhole tools, which are compact devices that can be used in relatively inexpensive, small-diameter exploratory wells. A joint DOE/industry program to evaluate slimhole, high-temperature, memory data-logging tools for reservoir evaluation was initiated in FY 1992. These tools measure well characteristics, such as temperature, and store the data rather than transmitting the data to the surface. When the data-logging tool is retrieved from the well, the data can be retrieved from the tool's computer memory.

A similar cost-shared program for reservoir testing using slimhole flow tests and multi-well tracer tests was also initiated with an industrial partner at Steamboat Hills, Nevada. Researchers also began construction of a slimhole, high-temperature, potassium-uranium-thorium memory logging tool, which will be capable of measuring in-hole geochemical conditions that influence corrosion and scaling.

Geothermal Drilling Organization. The GDO supports industry's application of new technology developed by the program. Although similar in structure and intent to GTO, GDO concentrates exclusively on the transfer of new drilling technologies to industry. Industry identifies the technologies and provides at least 50% of all project costs.

During FY 1992, GDO supported Unocal's commercialization of the high-temperature borehole televiewer by field testing and providing design assistance for an improved televiewer. Unocal plans to establish a commercial televiewer service to provide support to other developers and to facilitate worldwide geothermal operations.

Energy Conversion Technology

Conversion technology research aims to increase the efficiency of geothermal power conversion systems by maximizing the amount of electricity generated for each unit of geothermal fluid produced; developing cost-effective, durable materials of construction for handling hot brine, steam, cooling water, and binary fluids; and designing innovative brine disposal methods to further reduce operating costs. When combined with other new technologies, these improvements will contribute to developing lower-temperature geothermal resources that are not cost-effective using today's technology.

Heat Cycle Research. The current principal emphasis of heat cycle research is to improve the performance of binary cycle technology. These improvements should lower the costs of generating electricity with binary processes and increase the utilization of the more abundant, lower-temperature reservoirs not suitable for flash steam technology. Achievement of such improvements requires the use of advanced engineering tools and methods, which are being validated by tests at the Heat Cycle Research Facility (HCRF).

During FY 1992, HCRF researchers continued to gather data on the performance of condensers in nonvertical orientations. The researchers completed supercritical vaporization tests to confirm the theoretical predictions of enhanced efficiencies under these conditions. A test nozzle with a laser system for droplet measurements was also installed on the HCRF in FY 1992. The nozzle will be used to investigate turbine expansions with reduced superheat.

The data from all of these tests will be used to quantify the accuracy of computer codes for modeling the performance of binary cycles.

The Heat Cycle Research Facility (HCRF) has been used to evaluate advanced binary power systems in California's Imperial Valley since the mid-1980s. Techniques proven at the HCRF could boost binary power plant performance by 20%.

Materials Development. Because the performance, cost, and lifetime of materials are critical to the economics of hydrothermal systems, researchers continue to work on increasing the temperature and chemical tolerance of metallic and nonmetallic construction materials. One focus of this work is on cements, which are used to complete geothermal wells by bonding metal liners to the inside of the hole. The failure of these cement bonds can lead to premature loss of a geothermal well. In FY 1992, researchers investigated new formulations to improve the pumpability of phosphate-modified calcium aluminate cements, which are resistant to attack by carbon dioxide. The research focused on incorporating lightweight microspheres to reduce the density of the cement and adding hardening retardants to keep the cement pumpable longer. The long-term compatibility of the microspheres was established and the most promising hardening retardants were identified.

Also in FY 1992, field testing of corrosion-resistant, polymer-cement-lined casings, installed in FY 1991, continued at The Geysers. That field test was also expanded by installing two polymer-cement-lined pipe tees of the type used in steam collection systems.

Advanced Brine Chemistry. When the pressure and temperature of geothermal fluids is reduced during production and extraction, the chemical equilibrium of the fluid is disturbed, causing dissolved minerals to precipitate. These precipitates form scale, which builds up and restricts flow through the rock, as well as through the production tubing, distribution system, and plant equipment. Advanced brine chemistry research increases the understanding of this problem by gathering chemical thermodynamic data for the fluids, developing mathematical equations consistent with those data, and creating computer models that incorporate those mathematical equations.

In FY 1992, an advanced computer model of geothermal fluid behavior was repackaged to make it more user friendly. It is now available in a personal computer version for IBM and Macintosh computers. The model was also tested by applying it to several field situations. In addition, refinements were made on the mathematical equations for calcite scale formation and for the nonideal behavior of several ternary gases.

Advanced brine chemistry research also supports research on biochemical processes for remediating solid wastes from geothermal brines, which can contain heavy metals. Researchers have developed bacterial strains that can achieve fast rates of heavy metal removal (greater than 80% in less than 25 hours) at 55°C. Based on this finding, construction of a prototype biochemical remediation system, capable of operating under highly acidic conditions and high temperatures, was initiated in FY 1992. This system will be used to generate data for designing and building a larger prototype system for field testing of the technology.

Geopressured-Geothermal Research

Research with the goal of developing our nation's geopressured-geothermal energy resources has been organized into two main tasks:

- Well operations
- Geoscience and engineering support.

Well Operations

The Well Operations Task consists of pressure buildup tests and high-flowrate well tests designed to expand our knowledge of reservoir production performance, surface handling systems, well-injection procedures, brine chemistry and scale inhibition, and automation of production systems. Field tests are conducted at the Pleasant Bayou and Gladys McCall wells, which were drilled specifically for scientific study of geopressured aquifers, and the Hulin well, a well-of-opportunity donated by industry.

During FY 1992, flow tests at the Pleasant Bayou well in Brazoria County, near Houston, Texas, provided data for understanding and predicting the performance of the reservoir, surface facilities, and injection system. This well is about 4500 m deep, with a brine temperature of 150°C. Long-term pressure buildup tests continued at the Gladys McCall well in Cameron Parish, Louisiana. This well extends into a geopressured reservoir 4620–4715 m deep, with a brine temperature of 146°C. During the production phases of testing, the Gladys McCall well produced more than 4.3 million m^3 of brine and 19 million m^3 (671 million ft^3) of methane. The Hulin well, also located in Louisiana, was not tested in FY 1992.

Geoscience and Engineering Support

Geoscience and engineering support is focused on analyzing geopressured well data (obtained from well operations testing) to understand the performance of geopressured reservoirs under long-term, high-volume production. Reservoir analysis and the refinement of the DOE geopressured reservoir model are designed to gain a better understanding of the mechanisms that drive fluid production and to provide the means to predict long-term production based on short-term tests.

FY 1992 accomplishments included integration of new data into the models of the Pleasant Bayou and Gladys McCall reservoirs. Also, continued environmental monitoring at the test wells offered no indication of any significant environmental impacts related to any well activities.

The decision has been made to discontinue further research on geopressured-geothermal energy to focus on priority needs for hydrothermal energy.

Hot Dry Rock Research

Hot dry rock research seeks to develop practical, economic technology for recovering thermal energy

A long-term flow test was initiated at the Fenton Hill demonstration project in FY 1992. The test will help demonstrate the feasibility of hot dry rock technology.

from naturally heated, impermeable rock at accessible depths. Research is conducted within two projects:

- Fenton Hill operations
- Scientific and engineering support.

Fenton Hill Operations

A small, experimental hot dry rock reservoir was created at Fenton Hill, New Mexico, and successfully tested in 1976–1980. The system was essentially trouble free, and some of the heat produced was used to operate a small binary-cycle generating unit. Subsequently, a larger, hotter reservoir was created. During a 30-day flow test, that reservoir produced fluid with a surface temperature of 193°C, well within the range necessary for power generation.

This successful result led to preparations for a long-term flow test, which required the installation of a system capable of cooling and reinjecting the fluid, adding makeup water, and removing any gases or suspended solids. In FY 1992, the final surface equipment was installed, the major subsystems were checked out, preliminary system tests were carried out, and a 3-month flow test was performed. During this period, the system operated at 99% availability, producing about 4 MW_t at a temperature of roughly 184°C. Flow testing will resume in FY 1993. Completing this test will be a significant milestone in hot dry rock research; it will provide information on the impedance, thermal drawdown, energy output, and water consumption of a hot dry rock system at the scale of a small modular power plant.

Scientific and Engineering Support

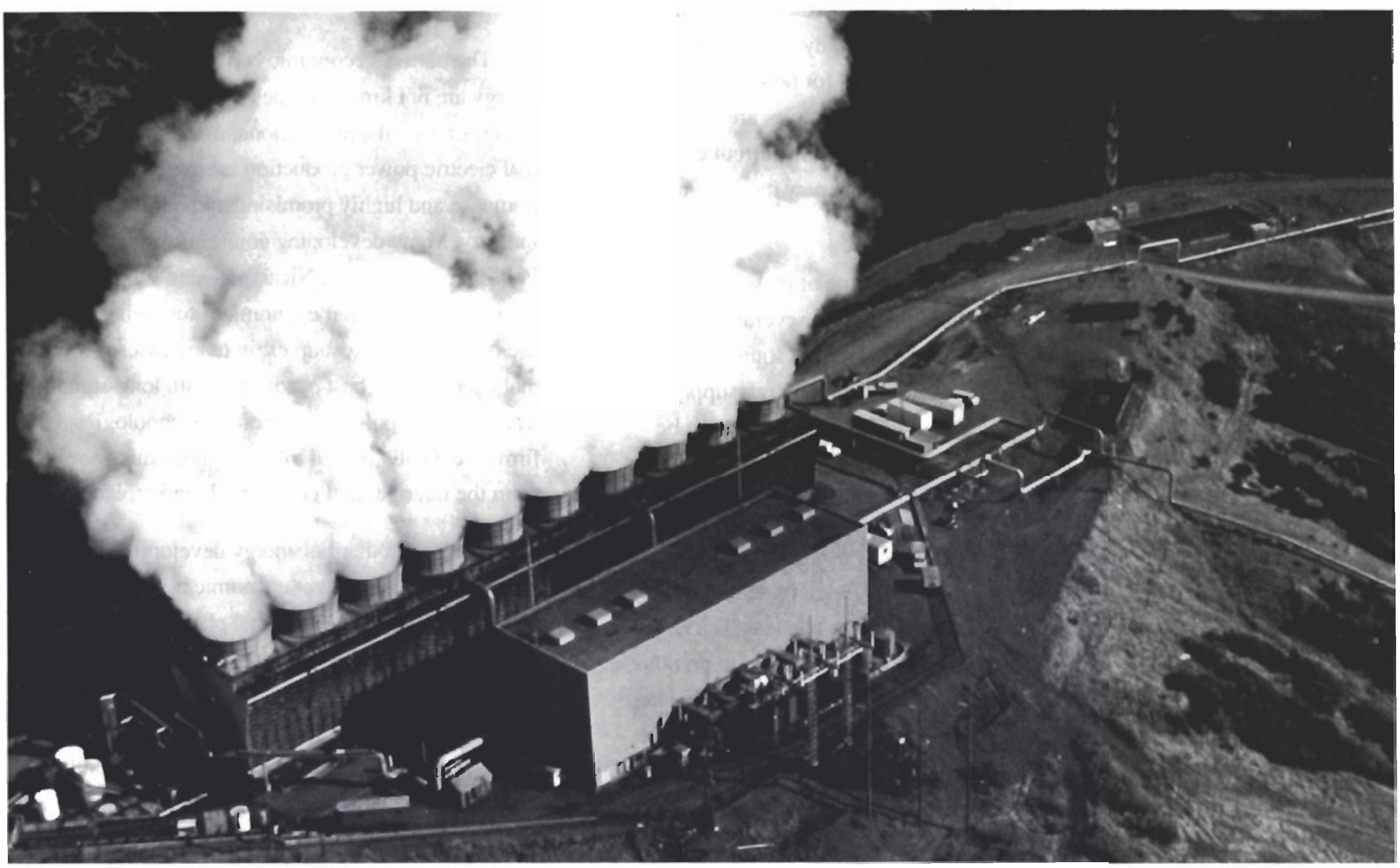
This project provides the support necessary to draw substantive conclusions about the long-term flow test at Fenton Hill. It includes refining the reservoir model, conducting downhole experiments, analyzing test data, and verifying reservoir performance. A major element of this project is providing downhole instruments and equipment by modifying existing downhole tools or developing new tools when necessary. During FY 1992, geophysical and geochemical investigations were conducted in conjunction with the initial flow testing. Tracer tests and chemical analyses were used to evaluate the fluid flow through the reservoir, and microseismic measurements from nearby monitoring wells were used to better understand the structure of the reservoir.

PROGRAM MANAGEMENT

DOE's Geothermal Division provides the central leadership to ensure that program activities are consistent with national energy policy and priorities.

The Geothermal Energy Program is managed by the director of the Geothermal Division at DOE Headquarters in Washington, D.C. The division provides the central leadership necessary to ensure that Geothermal Energy Program activities are consistent with national energy policy and priorities. The management of technical activities is decentralized among DOE field offices and national laboratories to make sure that technical expertise is available to supervise the research.

To ensure the continuing exchange of technical progress and programmatic concerns, the Geothermal Division sponsors an annual program review during which the field offices, national laboratories, universities, and industry contractors present the results of their work. This review is open, and the public is encouraged to attend. In addition, the participants in each research category gather twice a year for a program review to discuss research activities and plans in more detail.



The Geysers in northern California is the world's largest producer of geothermal power. Geothermal energy is a reliable, environmentally benign, domestic source of electricity that provides many economic benefits.

THE OUTCOME

Geothermal energy is a large domestic energy source; geothermal power plants produce power competitively today and can be brought on line quickly in case of a national energy emergency.

Geothermal energy makes a significant contribution to the nation's energy mix, supplying heat and electricity from dry steam and high-quality hydrothermal liquids. Today, these resources supply about 8% of all electricity used in California, and the growth of the industry in many areas is constrained only by the lack of demand for new power capacity. However, DOE research initiatives are still needed to improve the economics of the current geothermal technologies and to develop new methods and technologies.

The successful outcome of these research initiatives will benefit our nation in several ways. First, geothermal energy offers a large source of secure, domestic energy to add to our energy supply portfolio. Moreover, geothermal plants can be brought on line quickly in case of a national energy emergency.

Second, geothermal energy is a highly reliable resource, resulting in very high plant availability. For example, new dry steam plants at The Geysers are operable more than 99% of the time. In other words, geothermal plants offer an attractive alternative to fossil-fired or nuclear power plants for baseload power: they can operate 24 hours a day and are unaffected by daily or seasonal variations.

Third, geothermal energy offers a source of electricity that is relatively benign environmentally. Today's hydrothermal power plants with modern emission controls have proven to have minimal environmental effects. Moreover, carbon dioxide emissions, which some scientists have identified as a major culprit in the global warming phenomenon, are only a fraction of those of fossil-fired power plants. And the results so far with geopressured, hot dry rock, and magma resources suggest that they, too, can be operated with minimal environmental effects.

Fourth, the geothermal electric power and direct-use industries present a golden opportunity for promoting the economic vitality of the nation. Hundreds of jobs are created to directly support the planning, exploration, construction, and operation of new geothermal plants. Indirect support of the geothermal plants will create several thousand more jobs. Beyond the direct regional economic benefits, geothermal development will also stimulate manufacturing industries and financial markets on a national scale.

The nation's economic benefits from geothermal energy are not limited to the development of domestic resources—the international market for geothermal electric power production is emerging as an immense and highly promising arena for U.S. industry. Many developing countries, such as the Phillipines, Indonesia, Nicaragua, and El Salvador, are realizing that their economic future relies on the use of indigenous resources; in many cases, geothermal energy is the best candidate. With long-standing leadership in applying geothermal technologies, U.S. firms are ideally poised to enjoy enormous gains from the international geothermal marketplace.

Finally, geothermal energy development offers another significant direct economic benefit: royalty and leasing fees for geothermal plants on public lands are paid to the federal government. Half of this revenue is returned to the state in which the public lands are located. More than $17 million in geothermal royalty and rental fees are collected annually. With aggressive promotion of geothermal energy via an enhanced federal research and development program, annual royalty and leasing revenues could soar to hundreds of millions of dollars.

The progress made by DOE's Geothermal Energy Program, working in cooperation with the U.S. geothermal industry and utilities, gives confidence that the geothermal resource continues on track toward fulfilling its tremendous promise. The program focuses on the technologies that have the best chance of success and that can make the biggest difference in developing cost-competitive geothermal systems. Success during the 1990s will allow industry to exploit today's applications and develop new ones to meet our nation's future energy needs.

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